MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

EME3206 – CONTROL ENGINEERING

(ME)

06 MARCH 2017
02.30PM - 04.30PM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages including cover page with 4 Questions only.
2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.
4. Table of Transform pairs has been included in Appendix.

Question 1

(a) Figure Q1 (a) shows a mass spring damper system in which the input force $f(t)$ results in masses motions $x_1(t)$ and $x_2(t)$. Assuming the contacts between the masses (m_a and m_b) and the ground are frictionless; drive the dynamic model equations of the system. Obtain Laplace transformations of the model equations, assuming zero-initial-conditions. Draw the block diagram of the system relating the input Force, $F(s)$, to the output motion, $X_2(s)$. Obtain the transfer function $\frac{X_2(s)}{F(s)}$.

[16 marks]

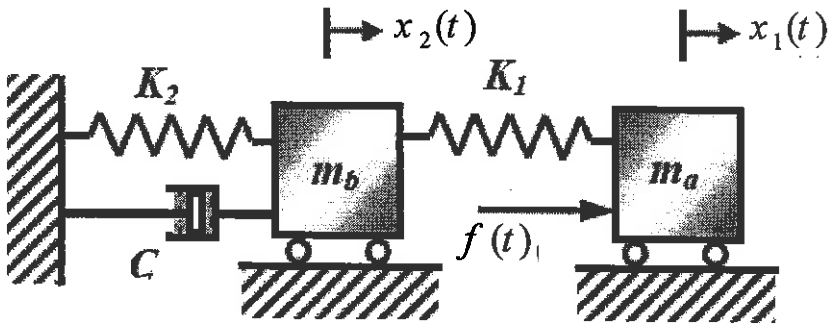

Figure Q1 (a). A mass-spring-damper system

(b) Simplify the block diagram shown in Figure Q1(b) and obtain the closed loop transfer function $\frac{C(s)}{R(s)}$.

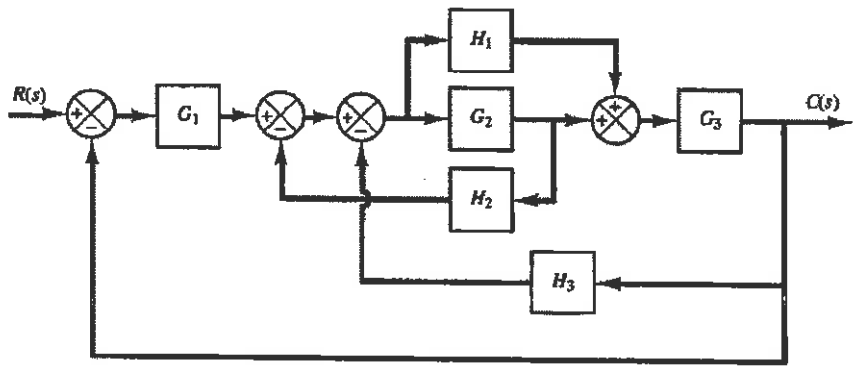

Figure Q1(b). Block diagram of a system

[9 marks]

Continued...

Question 2

The open-loop transfer function $G(s)$ of a unity-feedback system is shown in Figure Q2.

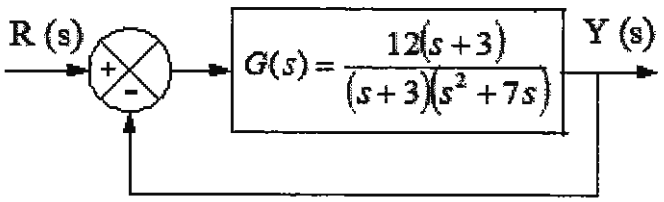

Figure Q2

(a) Find the output response $y(t)$ if the input is unit-step.

[11 marks]

(b) Find the following terms of second-order closed-loop system:

(i) Damping ratio

(ii) Natural frequency

(iii) Settling time

[7 marks]

(c) Determine the position error constant, velocity error constant, Acceleration error constant and steady-state error for unit step response.

[7 marks]

Continued...

Question 3

(a) Figure Q3 (a.1) shows a welding robot used in automobile plant. The welding head requires rapid and accurate response to move to different position on the body of automobile.

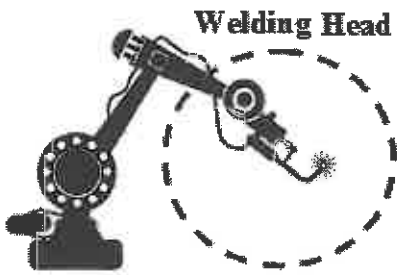

Figure Q3 (a.1)

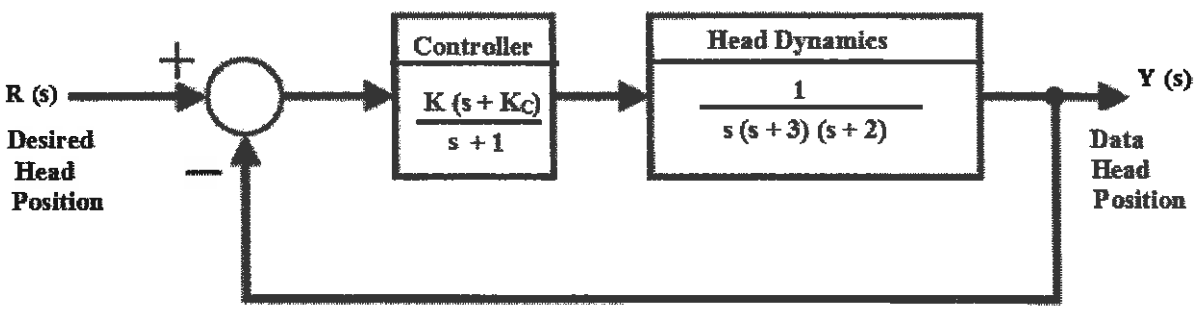

Figure Q3 (a.2)

Figure Q3 (a.2) shows the block diagram of welding head positioning system. Assume $K = 40$, apply Routh-Hurwitz Criterion to determine the range of parameter K_C so that the system is stable.

[10 marks]

Continued...

(b) Consider the negative feedback system shown in Figure Q3 (b) where $G(s)=\frac{1}{s(s+5)(s+10)}$, $H(s)=1$ and K is a gain parameter. Construct and label the root locus of the system. [*All eight steps of root locus construction analysis must be shown. Justify your answer if particular step is not required.*]

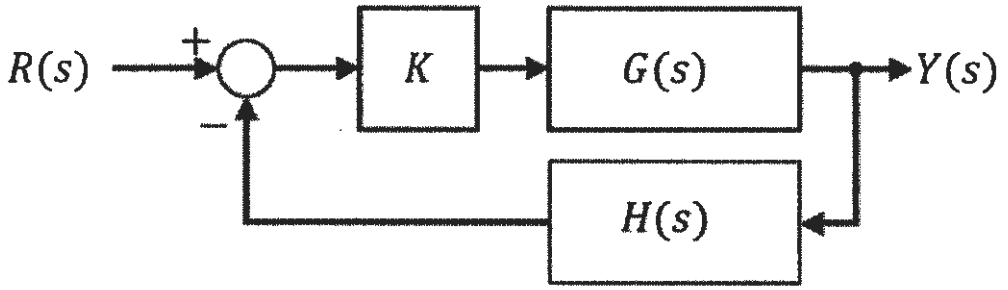

Figure Q3 (b)

[15 marks]

Question 4

(a) Prove that polar plot of sinusoidal transfer function

$$H(j\omega)=\frac{(j\omega A)}{(1+j\omega A)}, \text{ for } 0\le\omega\le\infty$$

is a semi-circle. Also find the center and radius of the circle.

[7 marks]

(b) The Nyquist Plot (polar plot) of the open-loop frequency response of a unity-feedback control system is shown in Figue Q4 (b). Assume that the Nyquist path in s-plane encloses the entire right-half s-plane. If the open-loop transfer function has no poles in right half s-plane. Determine whether the designed closed-loop system is stable or not?

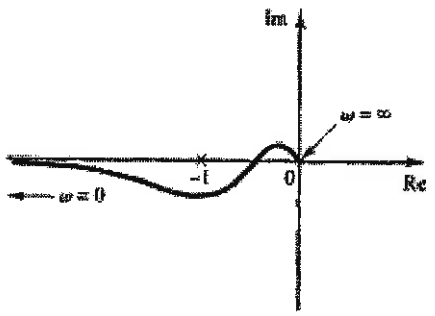

Figure Q4 (b)

[3 marks]

Continued...

(c) Find the state equation for the designed translational mechanical system as shown in Figure Q4 (c).

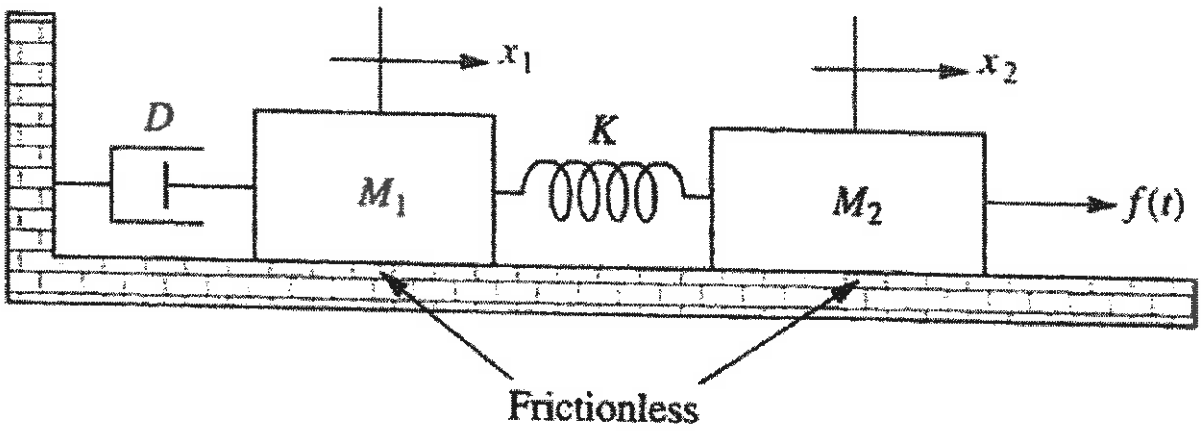

Figure Q4 (c)

[9 marks]

(d) Construct the complete state diagram of the differential equation given as;

$$\frac{d^n y(t)}{dt^n} + a_n \frac{d^{n-1} y(t)}{dt^{n-1}} + ... + a_2 \frac{dy(t)}{dt} + a_1 y(t) = r(t)$$

[6 marks]

Continued...

Appendix – Laplace Transform Pairs

f(t)	F(s)
Unit impulse δ (t)	1
Unit step u(t) = 1	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!}$ (n = 1, 2, 3, …)	$\frac{1}{s^n}$
t^n (n = 1, 2, 3, …)	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at} \cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$1-\cos \omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t - \sin \omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin \omega t - \omega t \cos \omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega} t \sin \omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t \cos \omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$

End of the paper